GENERALIZED HYDROLOGY

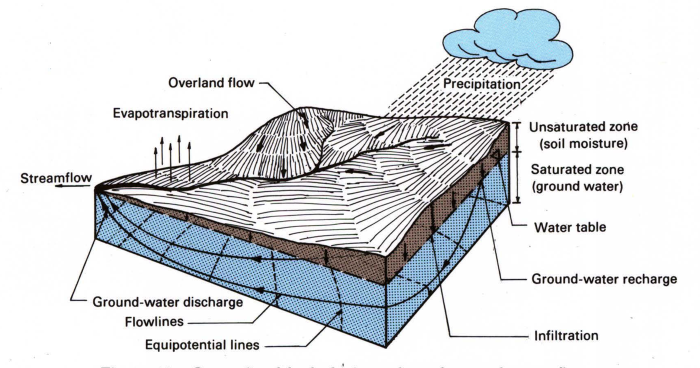

Figure 10.—Generalized hydrologic cycle and ground-water flow system.

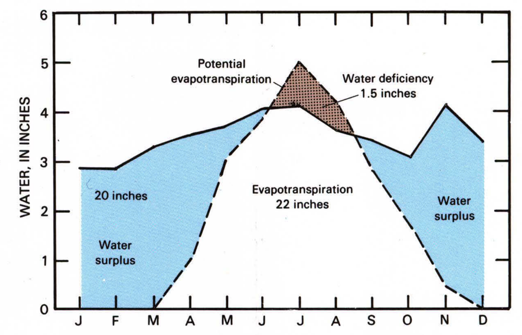

Figure 11.—Water balance of the Chicopee River basin.

GENERALIZED HYDROLOGIC CYCLE AND GROUND-WATER FLOW SYSTEM

The hydrologic cycle, a continuous circulation of water between the ocean, atmosphere, and land, is shown in figure 10. The water is transmitted to the atmosphere through evaporation from oceans, lakes, and streams, and through transpiration from plants. It returns again in the form of precipitation which either runs off the land into streams, lakes, and oceans, or infiltrates the soil and enters the ground-water system. The ground-water system is dynamic in that water is continuously in motion from the areas of recharge to the areas of discharge. In a typical ground-water flow system, this movement occurs through many different layers of geologic materials.

Water Balance

A water balance of the Chicopee River basin is shown in figure 11. Precipitation is fairly uniformly distributed throughout the year and totals 42 inches annually. Annual evapotranspiration equals 22 inches as determined by the method described in Thornthwaite and Mather (1957). During the months when precipitation is greater than evapotranspiration, there is a water surplus of 20 inches annually, which consists of runoff, diversions from the basin, and recharge to the ground-water system. Evapotranspiration exceeds precipitation during the months of July and August, which creates a water deficiency. The calculations used in this water balance are based on precipitation data collected in the town of Hardwick and air temperature data from Barre Falls Reservoir.

GROUND WATER

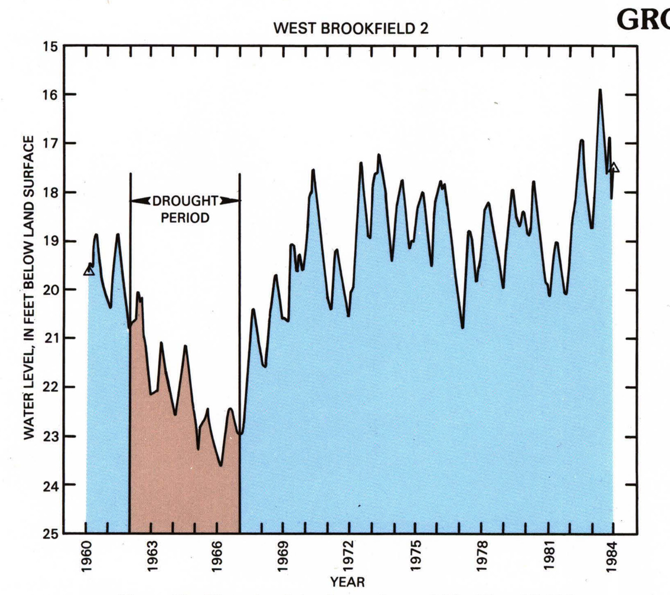

Figure 12.—Water levels in observation well West Brookfield 2.

Ground-Water Levels

The annual rise and fall of water levels under natural conditions is due to seasonal changes in precipitation. Long-term water-level decreases or increases are caused by extended periods of drought or above-normal precipitation, respectively. Water levels in the West Brookfield 2 observation well from 1959–83 are shown in figure 12. During the growing season, there is little, if any, net recharge to ground-water storage because evapotranspiration rates are high. Water levels decline steadily and reach a minimum in late summer or early fall. In the spring, large quantities of water released from melting snow and ice combine with normal precipitation to replenish aquifer storage causing ground-water levels to reach their annual peak.

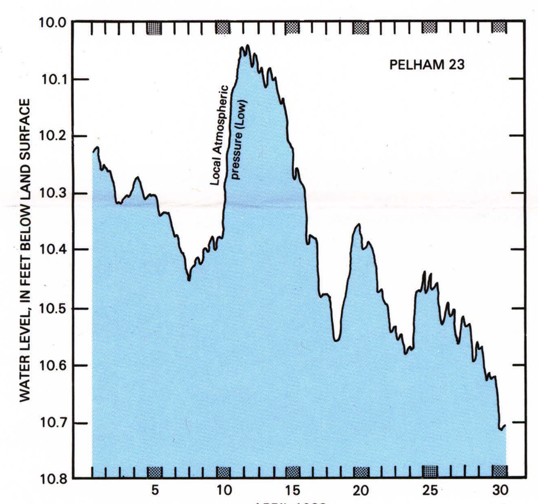

Figure 13.—Effects of atmospheric pressure and earth tides on water levels in a deep bedrock well.

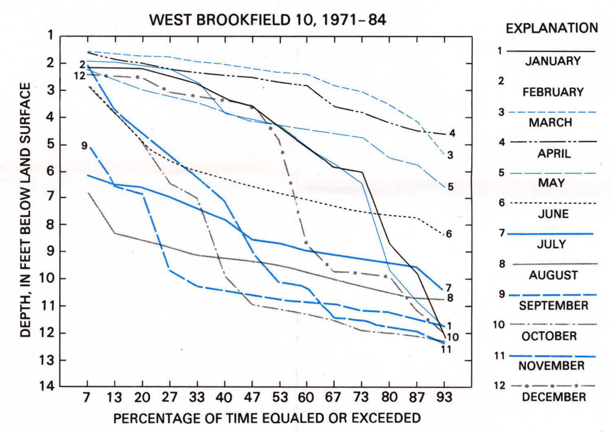

Figure 14.—Ground-water-level duration curves in observation well West Brookfield 10.

Effects of Atmospheric Pressure and Earth Tides on Water Levels in a Deep Bedrock Well

Ground-water fluctuations caused by atmospheric pressure and earth tides in a deep bedrock well are shown in figure 13. A continuous water-level recorder used to monitor the 740-foot deep observation well, Pelham 23, near Knights Corner in Pelham, detected minor water-level fluctuations that occurred every 12 hours 25 minutes caused by tidal forces exerted on the earth's surface by the sun and the moon. In addition to these earth tides, there is also evidence that water levels respond to changes in local atmospheric pressure. An increase in the atmospheric pressure causes the water level to decline, and conversely, a decrease in atmospheric pressure causes water level to rise.

Water-Level Duration

Water-level duration curves of observation well West Brookfield 10 (fig. 14) show the percentage of time water levels were equalled or exceeded for each month of the year. The curves indicate that the maximum ground-water storage in the aquifer occurs in the months of March and April.

Estimation of High Ground-Water Levels

Estimates of probable high ground-water levels are required by the Commonwealth of Massachusetts Department of Environmental Quality Engineering for siting of subsurface sanitary sewage disposal. Estimates also may be necessary at proposed construction sites and other places where there is concern about high ground-water levels. Annual ground-water levels generally reach their maximum altitude during the early spring; however, it is not always possible to measure ground-water levels in the spring because of time constraints. To estimate the high ground-water level for any site at any time of the year, Frimpter (1981) developed equations that relate the ground-water level at a site with the ground-water level at an observation well measured during the same month. Hydrogeologic and climatic conditions at the site and the observation well must be similar. The following equations were derived using data from observation wells in the vicinity of the Chicopee River basin for sites in different hydrogeologic environments. For a till site:

$$Sh = Sc - 1.52(WUW - 1.50)$$

For a sand and gravel site on a terrace:

$$Sh = Sc - 1.17(HHW - 9.23)$$

For a sand and gravel site in a valley:

$$Sh = Sc - 0.68(GKW - 4.99)$$

Where,
- Sh is the estimated depth to probable high water level at the site,
- Sc is the measured depth to water at the site,
- WUW is the measured depth to water in observation well West Brookfield 10,
- HHW is the measured depth to water in observation well Hardwick 1, and
- GKW is the measured depth to water in observation well Granby 68.

Example: Estimate of the probable high water level for a particular till site where Sc = 13.61 feet and WUW = 9.63 feet.

$$Sh = 13.61 - 1.52(9.63 - 1.50) = 1.25 \text{ feet}$$

The most recent water level for the observation wells can be obtained from the U.S. Geological Survey report, "Current Water Resources Conditions in Central New England", which is issued each month by the New England District office of the U.S. Geological Survey. Additional information for determining probable high ground-water levels and for using a different long-term observation well, are given in Frimpter (1981).

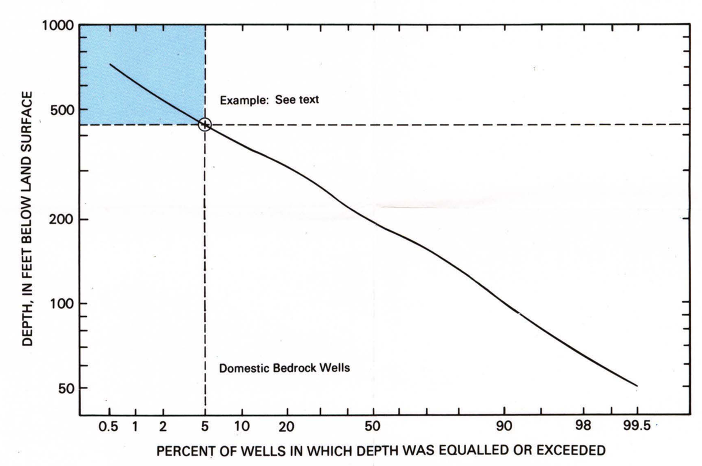

Figure 15.—Depths of domestic bedrock wells.

Depth of Crystalline Bedrock Wells

Most of the Chicopee River basin is underlain by crystalline rocks. Permeability of crystalline rocks is relatively low and decreases with depth. Most water-saturated fractures and joints in these rocks are located within 500 feet of the land surface. A probability curve of the depths of crystalline bedrock wells that have been drilled to supply water for domestic use is shown in figure 15. As shown by the example, the depths of only 5 percent of drilled domestic bedrock wells will equal or exceed 440 feet.

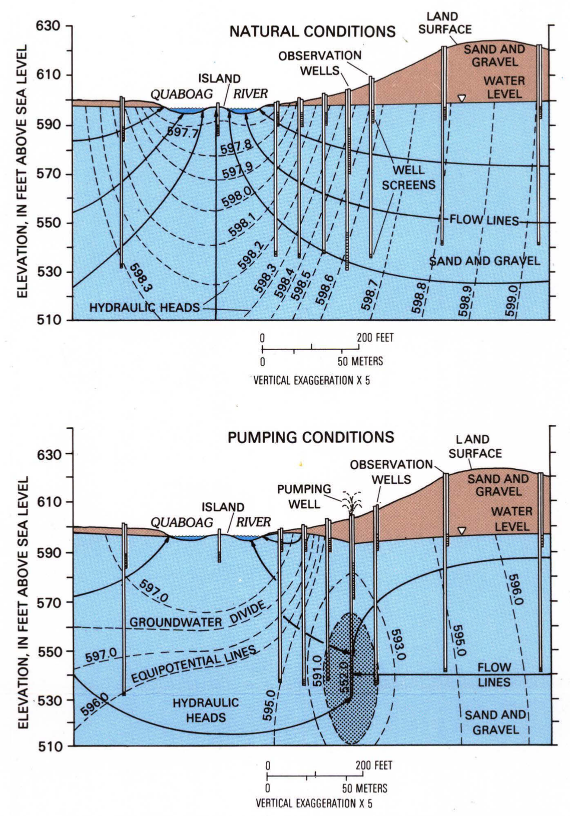

Figure 16.—Geohydrologic section at West Brookfield showing hydrologic conditions before and during aquifer test.

Ground-Water Flow at West Brookfield

An aquifer test was performed on a sand and gravel aquifer located along the Quaboag River near the intersection of State Routes 9 and 67 in West Brookfield during January 1984 (fig. 16). The flow lines and equipotential lines, determined from water-levels in the observation wells, are shown for both natural and pumping conditions.

Under natural conditions prior to pumping, ground water flows toward and discharges into the Quaboag River. After pumping at a rate of 500 gal/min for 5 days, ground-water flow is toward the pumping well. At this site and under these pumping conditions, recharge is not induced from the Quaboag River, as shown by location of the ground-water divide. However, pumping conditions are site specific and dependent chiefly on the pumping rate of the well, the hydraulic conductivity of the aquifer, and the degree of interconnection through the nearby streambed. In this aquifer test, streambed infiltration did not occur, and this may not be typical of other pumping well sites in the basin located near streams.

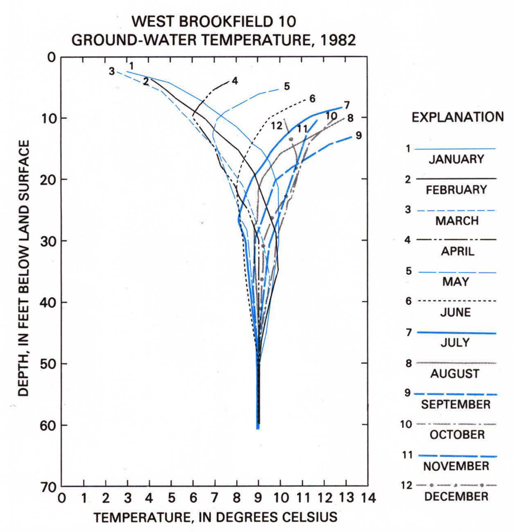

Figure 17.—Vertical temperature profiles of shallow ground water.

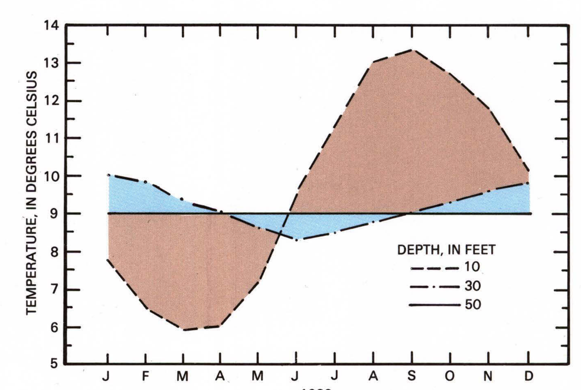

Figure 18.—Monthly temperatures in observation well West Brookfield 10.

Ground-Water Temperatures

Monthly temperature profiles of water in observation well West Brookfield 10 during 1982 are shown in figure 17. Monthly temperatures at depths of 10, 30, and 50 feet below land surface in observation well West Brookfield 10 during 1982 are shown in figure 18. Water temperature varies directly with air temperature at shallow depths. The amount of temperature fluctuation decreases with increasing depth. For example, at a depth of 10 feet, ground-water temperature fluctuates from 5.9 to 13.3°C during the year. At a depth of 50 feet, seasonal air-temperature fluctuations do not affect ground-water temperatures.

An aquifer in unconsolidated material acts as a heat source or sink depending on the time of the year. During the summer months, warm precipitation infiltrates the recharge area of the aquifer, percolates downward, and thus warms the soil and aquifer. Conversely, in the winter, cold precipitation and snowmelt cools the soil and aquifer as the water percolates below the seasonally frozen soil surface. As the water moves vertically down, it eventually comes to a level where the temperature remains at a constant 9°C.

WATER USE

Table 1.—*Municipal water use, 1980*

Municipality	Population 1980[1]	Population served by public supply[1], [2]	Percentage of population served	Surface water[1], in million gallons per day	Ground water[1], in million gallons per day	Self-supplied ground water[3], in million gallons per day	Total water use, in million gallons per day	Gallons per day per capita	Source of supply
Barre	4,102	3,000	73	0	0.27	0.08	0.35	85	Three wells and Barre Reservoir.
Belchertown	8,339	2,500	30	0	.24	.44	.68	81	Well field (21 wells).
Brookfield	2,397	1,400	59	0	.08	.07	.15	63	Three wells.
Chicopee	55,112	55,100	100	10.38	0	0	10.38	188	Springfield Water Department and Metropolitan District Commission.
East Brookfield	1,955	1,200	62	0	.12	.06	.18	92	One well.
Hardwick	2,272	1,600	70	0	.12	.05	.17	75	Five wells.
Hubbardston	1,797	0	0	0	0	.13	.13	72	Onsite self-supplied.
Ludlow	18,150	16,300	90	1.79	0	.14	1.93	106	Ludlow Reservoir.
Monson	7,315	5,000	68	0	.95	.17	1.13	153	Two wells and one standby well.
New Braintree	671	0	0	0	0	.05	.05	75	Onsite self-supplied.
New Salem	688	0	0	0	0	.05	.05	75	Onsite self-supplied.
North Brookfield	4,150	3,600	87	.47	0	.04	.51	123	North Pond, Doane Pond (standby).
Oakham	994	0	0	0	0	.07	.07	75	Onsite self-supplied.
Palmer	11,389	10,600	93	.40	.81	.06	1.27	112	Six wells, Graves Brook (upper and lower) Reservoirs.
Paxton	3,762	3,500	93	.25	0	.02	.27	72	Asnebumskit Reservoir.
Petersham	1,024	0	0	0	0	.08	.08	78	Onsite self-supplied.
Rutland	4,334	2,800	65	.24	0	.12	.36	83	Muschopauge Pond.
Spencer	10,774	5,000	47	.30	.07	.43	.80	74	Shaw Pond, one well.
Ware	8,953	7,200	80	0	.92	.13	1.05	117	Four wells.
Warren	3,777	3,600	95	0	.49	.01	.50	132	Six wells and well field, one standby well, Comins Pond, standby source.
West Brookfield	3,026	2,200	72	0	.25	.06	.31	102	Two wells.
TOTAL	154,981	124,600	80	13.83	4.32	2.26	20.41	132	

[1]Data from Massachusetts Division of Water Resources, 1983.
[2]Rounded to nearest hundred.
[3]Estimated on use of 75 gal/d per capita.

WATER QUALITY

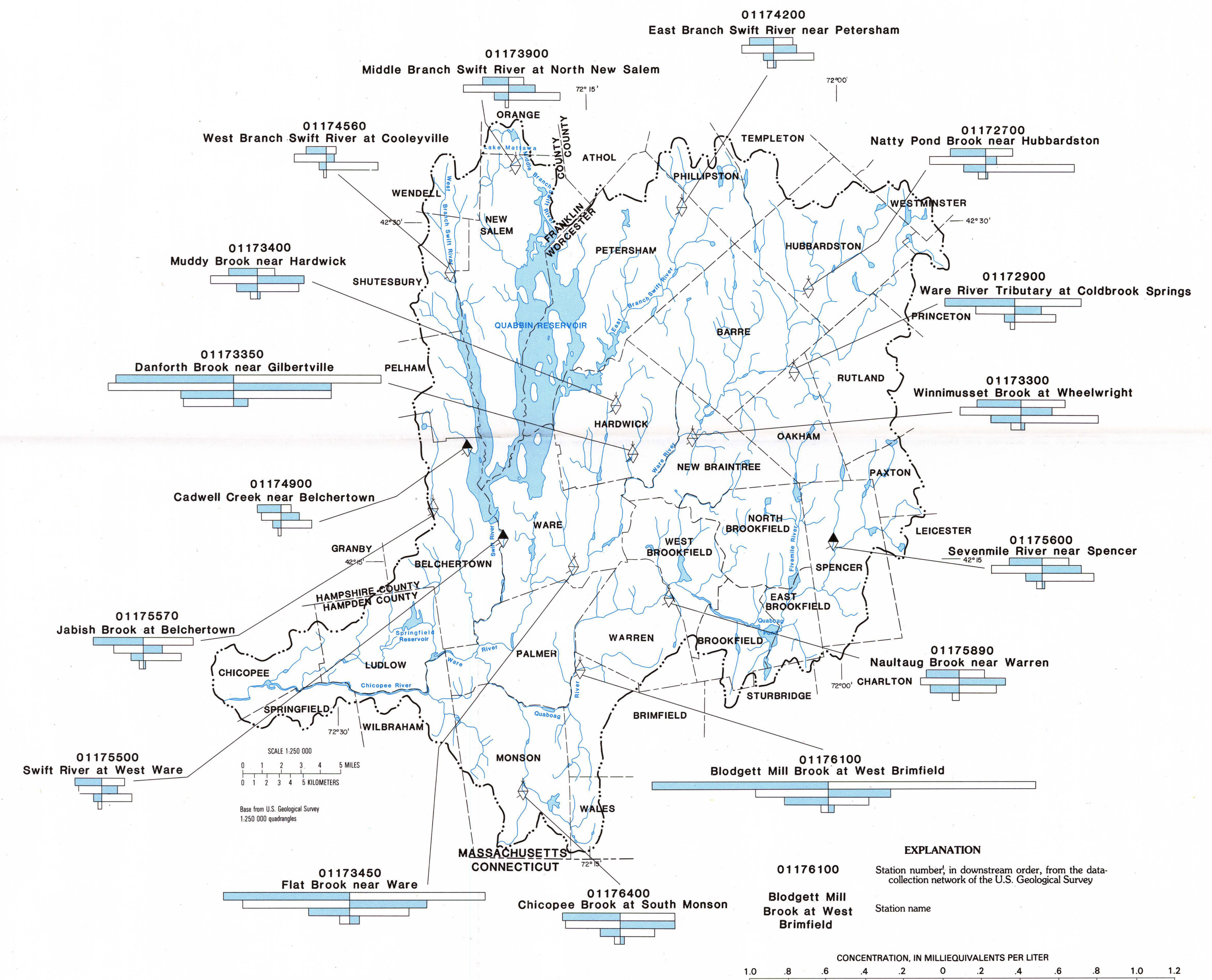

Figure 19.—Major-ion concentrations of surface water at selected stream sites

EXPLANATION

01176100 — Station number[1] in downstream order, from the data-collection network of the U.S. Geological Survey
Blodgett Mill Brook at West Brimfield — Station name

CONCENTRATION, IN MILLIEQUIVALENTS PER LITER
1.0 .8 .6 .4 .2 0 .2 .4 .6 .8 1.0 1.2
Na, Ca, Mg, K — Cl, HCO_3, SO_4, N

- Na — Dissolved sodium
- Cl — Dissolved chloride
- Ca — Dissolved calcium
- HCO_3 — Alkalinity as bicarbonate
- Mg — Dissolved magnesium
- SO_4 — Dissolved sulfate
- K — Dissolved potassium
- N — Dissolved nitrate plus nitrite as N
- Low-flow measurement station
- Continuous-record gaging station
- Chemical-measurement site
- Basin boundary
- City or town boundary
- County boundary
- State boundary

WATER QUALITY
Surface Water

Stream water was sampled for chemical analysis at 16 sites between August 31 and September 2, 1983. The site locations and corresponding common ion concentrations, in milliequivalents per liter, are shown in figure 19.

The dominant ions at Blodgett Mill Brook at West Brimfield and Flat Brook near Ware sites are sodium and chloride, largely derived from runoff containing road deicing salt. The Danforth Brook near Gilbertville site, located in an area of local dairy farming, has elevated concentrations of sodium, chloride, calcium, magnesium, sulfate, and potassium. The ion concentrations for all sites on tributaries of the Quabbin Reservoir are generally lower than other stream sites in the basin, however sulfate is the dominant ion. The presence of sulfate in water may be caused by wet and dry atmospheric deposition and by reactions involving the weathering of metallic sulfides in bedrock by oxygenated water.

Specific-conductance surveys of 33 stream sites were made during a low base-flow period, August-September 1981, and a high base-flow period, April-May 1982. The specific conductance of water provides a general indication of the content of dissolved solids for water that is not too saline or too dilute. During the low and high base-flow periods, the average specific conductance was 82 and 62 µmhos/cm at 25°C, respectively, showing that high base flow dilutes the water. Seventy percent of the sites had a specific conductance of less than 100 µmhos/cm at 25°C during the low base-flow period compared to 94 percent during the high base-flow period.

Ground Water

In 1976, the Massachusetts Department of Environmental Quality Engineering analyzed samples of ground water from the public-supply wells of all the towns in the study area. The samples were analyzed for common chemical constituents and physical properties, including specific conductance, turbidity, pH, and color. The results indicate that the ground-water quality is satisfactory for public and industrial use (Massachusetts Department of Environmental Quality Engineering, 1976).

Samples of ground water from 32 domestic bedrock wells in various types of bedrock, overburden, and topographic settings were analyzed for arsenic. No well contained arsenic concentrations that exceed Federal drinking water standards (U.S. Environmental Protection Agency, 1976).

WATER USE

Water use of municipalities in the basin in 1980 is shown on table 1. The total water for public supply and domestic use is 20.41 Mgal/d, which represents an average per capita use of 132 gal/d. About 89 percent of the water is provided by public-supply systems, and the remainder is supplied by private wells. As a general rule, the public water-supply systems rely on surface water and on shallow wells finished in stratified glacial materials. Generally, private wells are finished in bedrock. The following municipalities are not shown because the largest percentage of their area is outside the basin drainage boundary: Athol, Brimfield, Charlton, Granby, Hampden, Leicester, Orange, Pelham, Phillipston, Princeton, Shutesbury, Springfield, Sturbridge, Templeton, Wales, Wendell, Westminister, and Wilbraham.

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by
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1986